AN INVESTIGATION OF THE OCCURRENCE OF URANIUM AT CAMERON, ARIZONA

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by

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A thesis submitted to the faculty of the University of Utah in partial fulfillment of the requirements for the degree of

Master of Science

Department of Geology

University of Utah

March, 1957

This Thesis for the Master of Science degree

by

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ACKNOWLEDGMENTS

The writer wishes to express sincere appreciation to the Exploration Division of the United States Atomic Energy Commission, Grand Junction Operations Office, under whose auspices a major part of the data of this thesis were collected and by whose permission this material is included; to R. A. Laverty, E. B. Gross, and S. R. Austin of the Atomic Energy Commission who were associated with the writer and who materially assisted in mineral identification and laboratory analyses; and to Dr. W. L. Stokes, Dr. F. W. Christiansen, Dr. D. J. Jones, and Dr. L. B. Sand of the University of Utah for their criticisms and assistance in preparing the manuscript.

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AN INVESTIGATION OF THE OCCURRENCE OF
URANIUM AT CAMERON, ARIZONA

ABSTRACT

The purpose of this study is to describe the geology of the uranium deposits of the Cameron area, Arizona, and to establish geologic criteria which would serve as guides in exploration.

The Cameron area is approximately fifty miles north of Flagstaff, Arizona, and is composed of a belt of east-dipping Triassic sediments which lie on the southwest flank of the Black Mesa Basin.

Uranium deposits occur in the Chinle formation and the Shinarump conglomerate. Mineralization, found in small amounts in the upper parts of the Shinarump conglomerate, is of less economic importance than that which occurs in the Chinle. Production from the Chinle formation has come from nineteen deposits of two types: (a) bedded or lens deposits, (b) mineralized fossil trees.

Bedded or lens deposits occur in the lower sixty feet of the "C" division of the Chinle formation within elongate lenses representing scour filling. Lens sediments are cross-stratified, highly carbonaceous mudstones and argillaceous sandstones. Mudstones within a lens contain montmorillonite,

kaolinite and illite-type clays. Colors range from black to yellow in contrast to the grays of the surrounding clays. The lenses usually possess a halo, which varies in thickness from a few inches to several feet of bleached country rock.

Mineralized fossil trees are sporadically distributed throughout the "C" division and usually consist of individual logs, partly silicified, uranium-bearing, which often cap hummocks of clay.

Detailed mapping of the Huskon Number 1 deposit indicates the ore-bearing lens attains a thickness of forty feet and a width of five hundred feet. Joints within the lens have no apparent relationship to ore. The richest ore is closely associated with carbonaceous material.

Chemical analyses indicate the element molybdenum is more abundant in ore-bearing lenses and can be used to differentiate between barren and mineralized lenses. Vanadium, present in small amounts, shows no significant distribution pattern in the area.

The ore bodies are almost completely oxidized and possess a large assemblage of gangue minerals, some of which are quartz, montmorillonite, kaolinite, gypsum, limonite, jarosite, pyrite, and cobaltian wad. The principal ore minerals are uraninite, uranophane, torbernite, meta-torbernite, meta-autunite, schrockingerite and zippeite.

The following features are presented as useful criteria for exploration of uranium deposits in the Cameron area.

Stratigraphic position The favorable interval is the lower sixty feet of the "C" division of the Chinle formation.

Sandy lenses Sandy lenses which occur within the lower sixty feet of the "C" division generally possess anomalous radioactivity.

Carbonaceous material Radioactivity is found almost always where carbonaceous debris is encountered.

Color Light yellows, buff and rust colors are favorable.

Molybdenum Molybdenum, present in trace amounts, is more abundant in and around ore-bearing lenses.

INTRODUCTION

Purpose and scope

The Cameron area was first considered to have a uranium-producing potential early in 1952, when several small radioactive deposits containing uranium minerals were discovered. Subsequent reconnaissance work by the United States Atomic Energy Commission disclosed numerous radioactive anomalies in the area. These findings stimulated the need for more information about the uranium occurrences.

The purpose of this study is to describe the geology of the uranium deposits of the Cameron area, north central Arizona, particularly those occurring in the Chinle formation, and to establish geologic criteria which would serve as guides in physical exploration.

Location and accessibility

The Cameron area lies principally within the Navajo Indian Reservation in Coconino County, Arizona. Cameron is about fifty miles north of Flagstaff, Arizona, and is adjacent to the crossing of the Little Colorado River by U.S. Highway 89. The uranium-producing area is generally east of Cameron and parallels the Little Colorado River. It includes all or parts of Townships 27-29N, Ranges 9-10E (Gila and Salt River

Meridians) and constitutes an area of approximately 175 square miles.

The area is on the west flank of the Black Mesa Basin and is just north of the Black Point Promontory of the East Kaibab Monocline. (See Index Map, page 3).

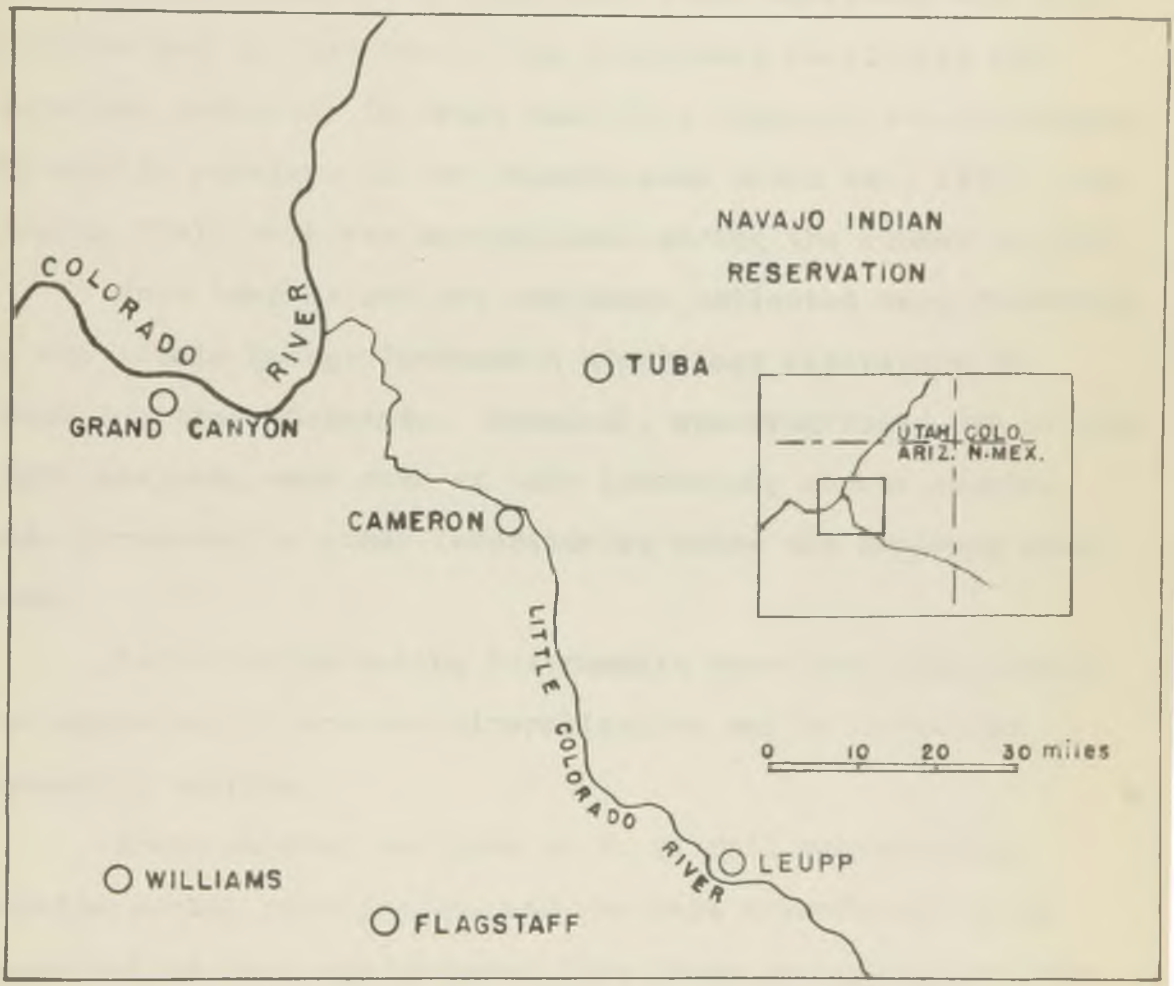
Access to the area is gained by U.S. Highway 89, which is the only paved road in this vicinity. There are no railroads, and commercial passenger traffic through the area is serviced by the Continental Bus Lines.

Many unimproved wagon trails and a few mine access roads cross the general area and provide points of departure for the more remote localities. The deposits located near Cameron usually are accessible by passenger automobile, but the more remote deposits can be reached only by vehicles with four wheel drive. During wet weather all unsurfaced roads become muddy and often are impassable.

Field work

Field work was conducted between September, 1953, and August, 1956. During September of 1953, while employed by the United States Atomic Energy Commission, the writer was assigned to the Cameron area by R. J. Wright, Chief of the Geologic Branch, Exploration Division, Grand Junction Operations Office. This assignment was part of the government program of stimulating domestic production of uranium ore.

PLATE I



INDEX MAP SHOWING LOCATION OF
CAMERON AREA, ARIZONA

Living quarters, a field office, and laboratory facilities were provided by the government at the small settlement of Cameron, Arizona. The necessary field equipment was also provided and utilization of the laboratory facilities and technical personnel in Grand Junction, Colorado was encouraged. The writer remained in the Cameron area until May, 1954. Concluding field work was accomplished during the summer of 1956.

Rock samples and ore specimens collected were forwarded to the Atomic Energy Commission mineralogy laboratory in Grand Junction, Colorado. Chemical, spectrographic and mineralogic analyses were made at this laboratory or the samples were forwarded to other laboratories where the analyses were made.

Radiation detecting instruments were used extensively for appraisal of uranium mineralization and in radiation intensity mapping.

Areal mapping was done on U. S. Soil Conservation Service aerial photographs, and the data transferred to an uncontrolled base map prepared from these photographs by the radial line method.

Detailed mapping was done by plane-table and alidade and by compass and tape methods.

Previous geologic work

Some of the earliest geologic work in the west included a general classification and dating of the sedimentary rock section in the Little Colorado River Valley.

The Ives Report (1861) describes the valley of the Flax River, (Little Colorado River) the Carboniferous rocks, and younger shales. Brief visits by geologists of the Wheeler Survey (1875) added stratigraphic details. Since 1900, Ward (1901), Gregory (1917), Reiche (1937), McKee (1938, 1951), Childs (1948), Babenroth and Strahler (1948), Williams and Barrett (1953), Wilson (1956), and others have studied the stratigraphy, structure and geomorphology of the area in considerable detail.

Climate and natural vegetation

Northern Arizona is considered to have an arid to semi-arid climate, except for a few areas of higher elevation. The valley of the Little Colorado River, extending southeast of Cameron, Arizona, is part of the Painted Desert, which is a highly elevated desert (elevation 4300-4800 feet) described by Childs (1948) as having "the hottest, driest climates of southwestern United States."

The diurnal and annual ranges of temperatures are great. The diurnal range often reaches 50 degrees Fahrenheit, and temperatures during the summer may reach 120 degrees Fahrenheit. The remaining months are pleasant for field work, with temperatures seldom reaching zero.

Rainfall as recorded at the weather station at Leupp, Arizona, a small settlement east of the area, reached a maximum in 1915 with 9.09 inches. The minimum of 2.52 inches was recorded in 1938. It is reported that the Leupp maximum is less than the maximum for any of the thirty-eight stations in northern Arizona, (Thornthwaite, Sharp and Dosch 1942).

The principal wet season occurs in late summer, and although a few general storms involve large areas, the most common summer rains are localized intense thunderstorms of short duration.

Natural vegetation consists of tamarisk and cottonwood trees, which grow only along the banks of the Little Colorado River or in the bottoms of protected tributary stream courses; and hardy varieties of desert shrubs, grass, and cactus which grow sparsely over parts of the area.

Land utilization

The land is chiefly used for yearround grazing of a limited number of sheep and horses.

When Beale (1858) entered the valley of the Little Colorado River, he mentioned the good grass and forage available. "What a stock country," he said, "I have never seen anything like it, and I predict for this part of New Mexico a large population." During the 1870's and 1880's thousands of cattle and sheep were easily supported by the ranges.

Severe droughts in the late 1880's, coupled with the large numbers of livestock, removed the vegetation to such an extent that when the rains once again came in the early 1890's, flash floods became commonplace (Colton 1937). This condition continues in large measure to the present, with a livestock population a fraction of that which the area was once capable of supporting.

GEOMORPHOLOGY

General statement

Both constructive and destructive geomorphic features are present in the area. Constructional features are mostly volcanic in origin. Depositional features are less conspicuous than the usual erosional forms of the area. The principal degradational process is stream erosion, active intermittently but vigorously during periods of rainfall, or along the Little Colorado River during the spring run-off. The Little Colorado River acts as base level for tributaries draining this area.

The geomorphology of the Little Colorado River Valley has been described in detail by Childs (1948), and the reader is referred to his work for a comprehensive treatment. A brief description of some of the more noticeable features of the landscape follows.

Little Colorado River Valley

The Little Colorado River in this area is classified as a subsequent stream whose valley has been principally cut along a belt of soft Chinle clays. Upstream from Cameron the river flows along the western side of a broad open valley with gentle pediment slopes rising eastward to the face of a cuesta known as Ward Terrace. The valley and pediment contain large areas of mud flats broken by hummocks and knolls typical of badland topography. (See Figure 1, page 13). The river flows on the more resistant sediments of the lower Chinle which dip gently to the east.

West of Cameron the Little Colorado River enters a narrow gorge in which it continues to its junction with the Colorado River in the Grand Canyon.

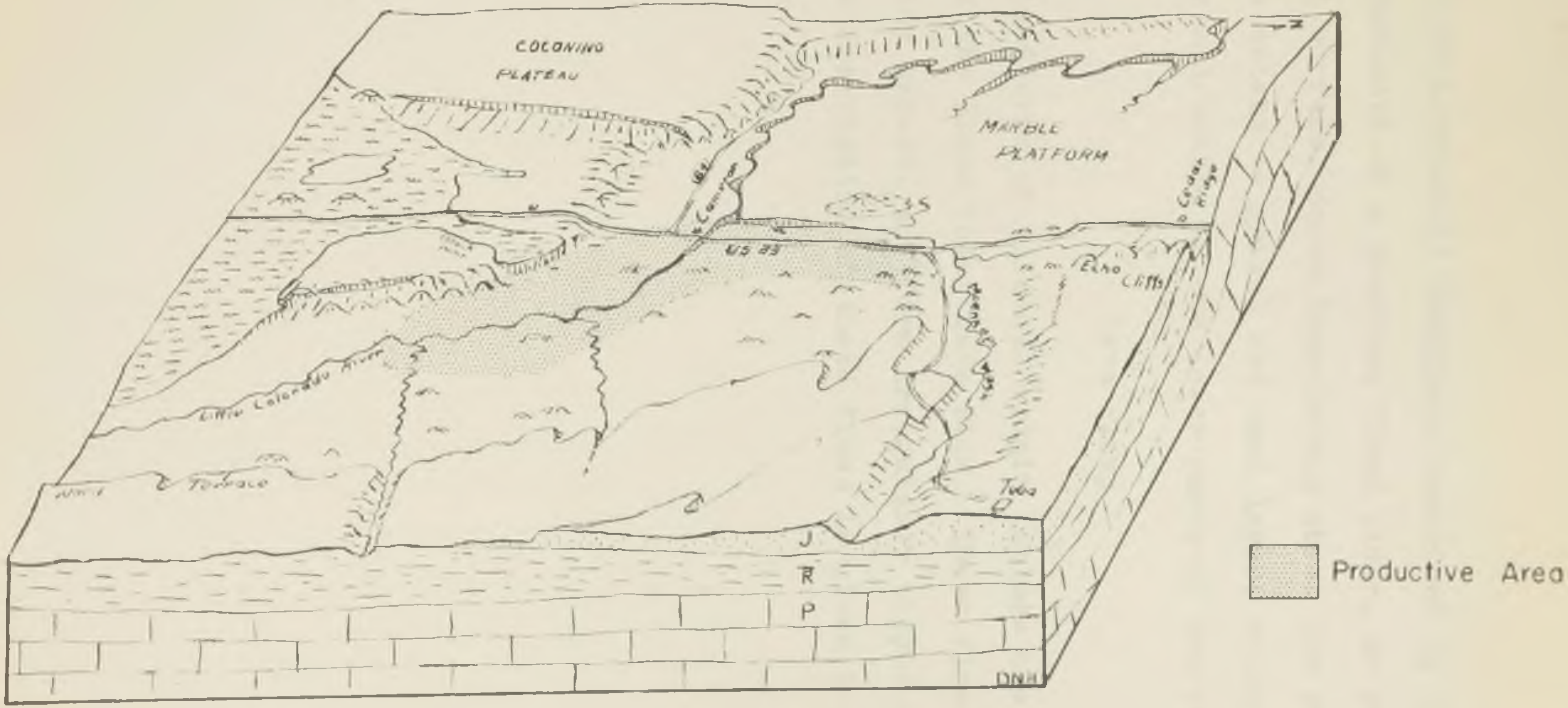
Ward Terrace (cuesta) merges into the Echo Cliffs monocline, north of the report area. (See block diagram, page 10).

Erosion surfaces

Three erosional surfaces have been described by Childs (1948), each being interpreted as having formed during a period of stability of the profile of the Little Colorado River. From the highest to lowest they are: (a) Black Point pediplane, (b) Wapatki pediplane, (c) Little Colorado River pediplane.

Reiche (1937), describes the occurrence of gravels and other lake sediments near Cameron which he called the Tolchaco Gravels, a Navajo name for the Little Colorado River. These gravels presumably were deposited in a lake formed by a temporary damming of the Little Colorado River by lava flows a short distance downstream. The gravels probably correspond

PLATE II



BLOCK DIAGRAM, CAMERON AREA ARIZONA

to the middle (Wapatki) pediplane described by Childs (1948).

Remnants of a previous flood plain, or possibly a pediment surface, occur immediately above the present river level as extensive gravel and sand layers which cap small hummocks and buttes in the lower parts of the valley.

Lava Flows

Landforms of volcanic origin include the Tappan Lava Flow and the Black Point Lava Flow. These flows are composed of olivine basalt, and form irregularly topped mesas. A more complete description of these flows is given in a following section.

FIGURE 1

View looking northeast at the clay hummocks in the Little Colorado River Valley, developed in the "C" division (Petrified Forest member) of the Chinle formation. Ward Terrace forms the line of horizon.

FIGURE 2

View looking north from near the Huskon Number 1 mine at the marker bed at the base of the "C" division, Chinle formation. It is composed predominantly of argillaceous sandstone with a thin quartzite capping.

Figure 1

Figure 2

STRATIGRAPHY

General statement

Sedimentary rocks exposed in the Cameron area range in age from Permian to Recent.

During late Paleozoic time, the region to the west was the site of the Kaibab Sea, where chiefly marine formations accumulated. (McNair, 1951). These marine formations pinch out or grade into predominantly continental or shallow water sediments eastward through the Cameron area.

Formations of Upper and Lower Triassic age are found in the Cameron area and are essentially composed of terrestrial or flood plain sediments. (McKee, 1951). The existence of a sea to the northwest during early Triassic time is indicated by the presence and increase in thickness of marine members in that direction.

Permian System

Kaibab limestone Along the Black Point Branch of the East Kaibab monocline south of Cameron, erosion has removed the overlying Triassic sediments from the steeply dipping Kaibab limestone. The Kaibab limestone is a gray, crystalline limestone which grades at the base and the top into alternating beds of buff calcareous sandstone and arenaceous limestone.

It is locally very fossiliferous, the fossils sometimes occurring in spherical pockets. Chert is common throughout the formation. It commonly weathers to a yellowish brown color and erodes to form cliffs and steep slopes both of which make it stand out in contrast to the bordering Triassic redbeds.

Triassic System

Moenkopi formation The Moenkopi formation outcrops along the western margin of the area, where erosion has removed the overlying cover of Shinarump and Chinle beds. The outcrop, generally trending south from Cameron with dips varying from zero to twenty degrees to the east, veers eastward and steepens in dip to form flat-irons and cuestas along the east-trending Black Point Branch of the East Kaibab monocline. It resumes a southern trend near Black Point where the monocline veers south.

The Moenkopi formation is of Lower Triassic age and is predominantly a flood plain deposit. It consists of micaceous, ripple-marked, interbedded sandstones and shales, red to buff in color, which commonly form slopes broken by ledges. The type section, 389 feet thick, measured by Gregory (1917), is located along Moenkopi Wash, a tributary entering the Little Colorado River about three miles below Cameron.

Shinarump conglomerate Outcrops of the Shinarump conglomerate are exposed in the more deeply-cut drainageways throughout the western part of the report area. This formation, considered by some to represent basal sediments of the Chinle formation, often occupies channels in the erosion surface on the Moenkopi formation. It varies greatly in thickness according to the depth of the channels and the elevation of its surface of accumulation. It is absent to the north near Cedar Ridge, Arizona, and in channels near Cameron approaches ninety feet in thickness.

The Shinarump consists largely of interbedded lenses of conglomerate containing chert and quartzite pebbles, conglomeratic sandstones, sandstone, shale, and mudstone. Carbonaceous material and partly silicified trees are common. The color varies with the lithology of the lenses, but is commonly light brown to buff on weathered surfaces.

Chinle formation Throughout the report area extensive exposures of Chinle sediments dip gently eastward. Composed largely of easily eroded claystones, it forms much of the surface material in the broad valley of the Little Colorado River.

Reports describing the Chinle formation and its upper Triassic flora and fauna are numerous. H. E. Gregory (1917), one of the first to study the Chinle, subdivided the formation as follows:

"Division A, the highest strata: Red, brown, pink or rarely gray calcareous shales and shaly sandstones, with a few thin beds of limestone and limestone conglomerate form banded walls at the base of the overlying massive Wingate sandstone; intricately carved into buttes or distributed as a patchy floor over the topmost limestone stratum of Division B....

"Division B: Gray, pink, and purple cherty limestone and light to dark red shale, in alternating bands. Limestone is massive or conglomeratic, in beds 1 to 6 feet thick, is highly resistant, and forms the caps of mesas and local plateaus; shales are thin, calcareous, mottled, and friable.......

"Division C: Shales and "marls", with rare calcareous sandstone, all lenticular, exceeding friable, varigated with tones of pink, red, ash, and purple; limestone conglomerate in lenses, short beds, and irregular masses is characteristic; gypsum is common and petrified wood almost universal; weathers into mounds, buttes, and immature mesas with typical badland expression.......

"Division D: Dark-red, chocolate-colored, or rarely gray shales and shaly sandstones (50 per cent); ripple marked, imbricated; brown conglomerate of lime and clay pebbles occurs in lenses; gypsum common; petrified wood in small amounts; bone fragments abundant; weathers into buttes and mesas divided by sharply cut miniature canyons, producing very rough topography....."

Recently, the United States Geological Survey placed the "A" division, which appears east of the report area, in the Wingate formation. The names Owl Rock member, Petrified Forest member, and Lower member are applied to the three remaining original divisions. (Harshbarger, et al, 1955).

The "B" division, (Owl Rock member) forms the cap and dip slope of the cuesta called "Ward Terrace," which borders the report area on the east.

The "C" division, (Petrified Forest member) comprises more than one-half the total thickness of the Chinle, (McKee, 1951), and outcrops over large areas of the valley of the Little Colorado River. Uranium production in the Cameron area comes largely from the lower parts of this division.

The "D" division, (Lower member) grades downward into the Shinarump conglomerate and is composed of lenses of conglomerate and alternating beds of sandstone, mudstone and claystone, and is characterized by much channel fill and cross stratification, (McKee, 1951). A section measured by the writer near Cameron, from the top of the Moenkopi to the bottom of the Petrified Forest member was 153 feet thick, of which 84 feet represented the Shinarump conglomerate.

Most of the uranium in the Cameron area is produced from a stratigraphic interval immediately above the "D" division of the Chinle formation. For this reason the contact of the "C" and "D" divisions deserves additional description. The horizon, here referred to as contact, is at the top of a quartzitic sandstone layer, very resistant to erosion, usually less than two feet thick, which overlies a massive to thin-bedded argillaceous sandstone, which possesses distinctively mottled colors ranging from purple through reddish-brown to yellows and grays. Color boundaries are particularly abrupt between the deeper colors and the grays. This bed, with its quartzite capping, averages about ten feet thick and occurs at the base of an extensive thickness of typical "Painted

Desert" clays and above the sand lenses of the "D" member. In combination with the quartzite capping it serves as an excellent marker horizon over the entire area. (See Figure 2 page 13).

Alluvium

Alluvium is found throughout the valley of the Little Colorado River along the banks of the major drainages and adjacent to the Little Colorado River. It is usually composed of sands and silts, but occasionally contains gravels.

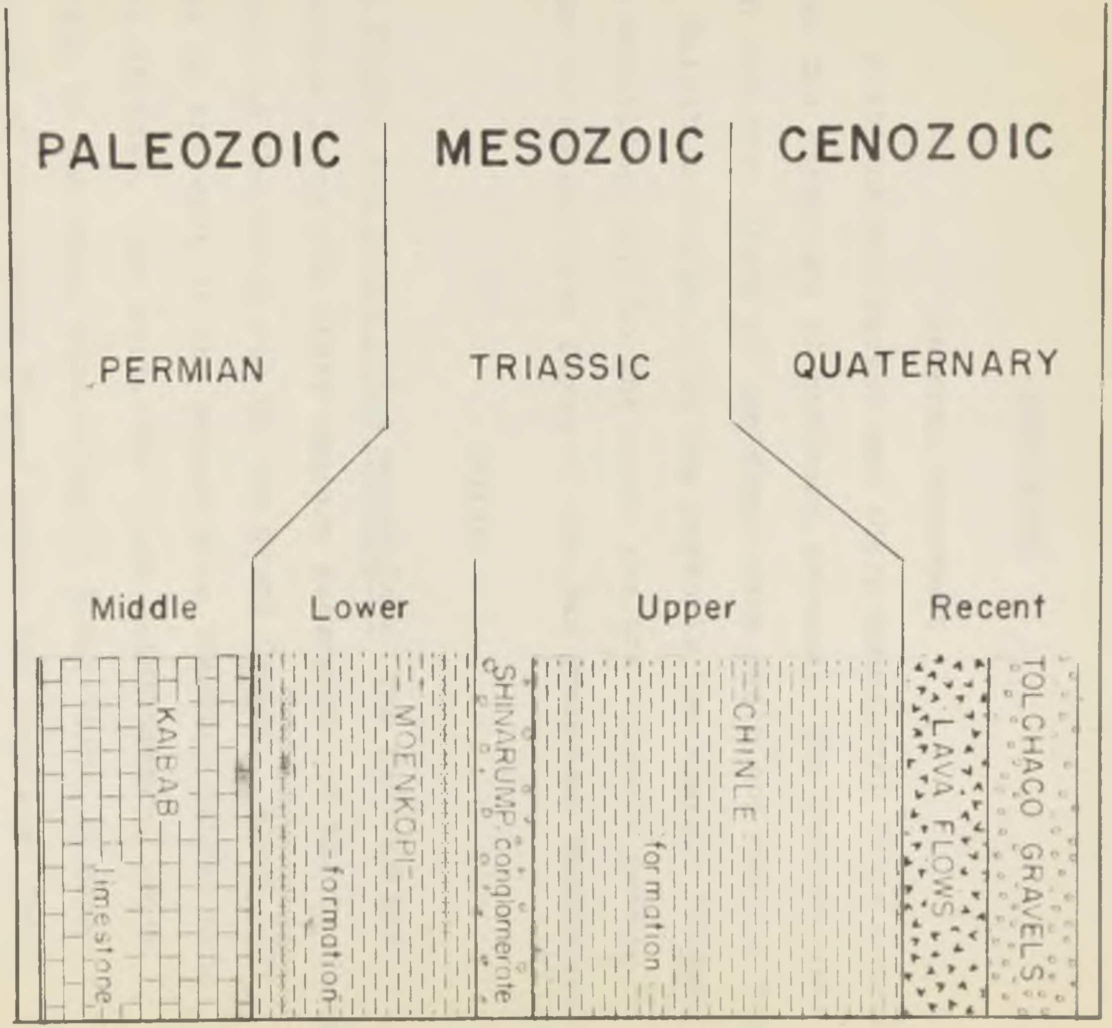
The remnants of previous erosion surfaces usually consist partly of alluvium. Of particular interest are the Tolchaco Gravels (described briefly in section on geomorphology), which locally attain a thickness of over one hundred feet. Reiche (1937), describes upper, middle and lower members of this lake deposit. The middle unit is called the Cameron beds and yielded fossil bones of the genus *Elephas*.

Lava flows

Two olivine basalt flows of recent age are located adjacent to the Cameron area. The most recent is the Tappan flow which attains a maximum thickness of 120 feet 1-1/2 miles southwest of Cameron, where it fills an abandoned channel of the Little Colorado River (Reiche, 1937).

The Black Point flow is about twelve miles southeast of Cameron and rests on the truncated beds of the steeply dipping Black Point Branch of the East Kaibab monocline. The source of these flows is to the south in the vicinity of the San Francisco Mountains. (Colton, 1937).

PLATE III



STRATIGRAPHIC SECTION

CAMERON ARIZONA

STRUCTURE

General statement

Plateaus and basins and sharp monoclinal folds characterize the structure of northern Arizona. The Cameron area is on the west flank of the Black Mesa Basin and east of the East Kaibab monocline. To the north is the sharply folded Echo monocline, and to the south are the volcanic peaks, cinder cones and lava flows of the San Francisco Mountains.

Folds

East Kaibab and Black Point monoclines The East Kaibab monocline forms the steep eastern escarpment of the Coconino Plateau on the south rim of the Grand Canyon. About five miles to the west of the report area the East Kaibab monocline divides. One part, the Black Point branch, veers sharply to the east, continuing to Black Point, a mesa composed of lava which flowed across the truncated fold. At the eastern margin of Black Point the monocline veers toward the south. This branch of the monocline forms a boundary to the productive area on the south and west sides. (See Plate IV, page 25).

North of the Black Point monocline the area is deformed by several small folds in the gently east-dipping strata.

These undulations are difficult to observe because of the lack of obvious reference horizons, and because of their small size. They were not mapped by plane table methods, and they could not be definitely discerned by use of the hand stereoscope, on aerial photographs. It is estimated that the flexing is in the order of twenty-five feet in one-half mile. Their location as plotted on Plate VIII was determined by visual observations made in the field.

Echo monocline The Echo monocline is not as long as the East Kaibab monocline, and the throw, about 500 feet, likewise is not as great, but in trend and eastward direction of downbending they are similar. The Echo monocline appears as a west-facing cliff of Triassic and Jurassic sediments, and thus in the Echo monocline the topography is just the opposite of the geologic structure. (Strahler, 1944).

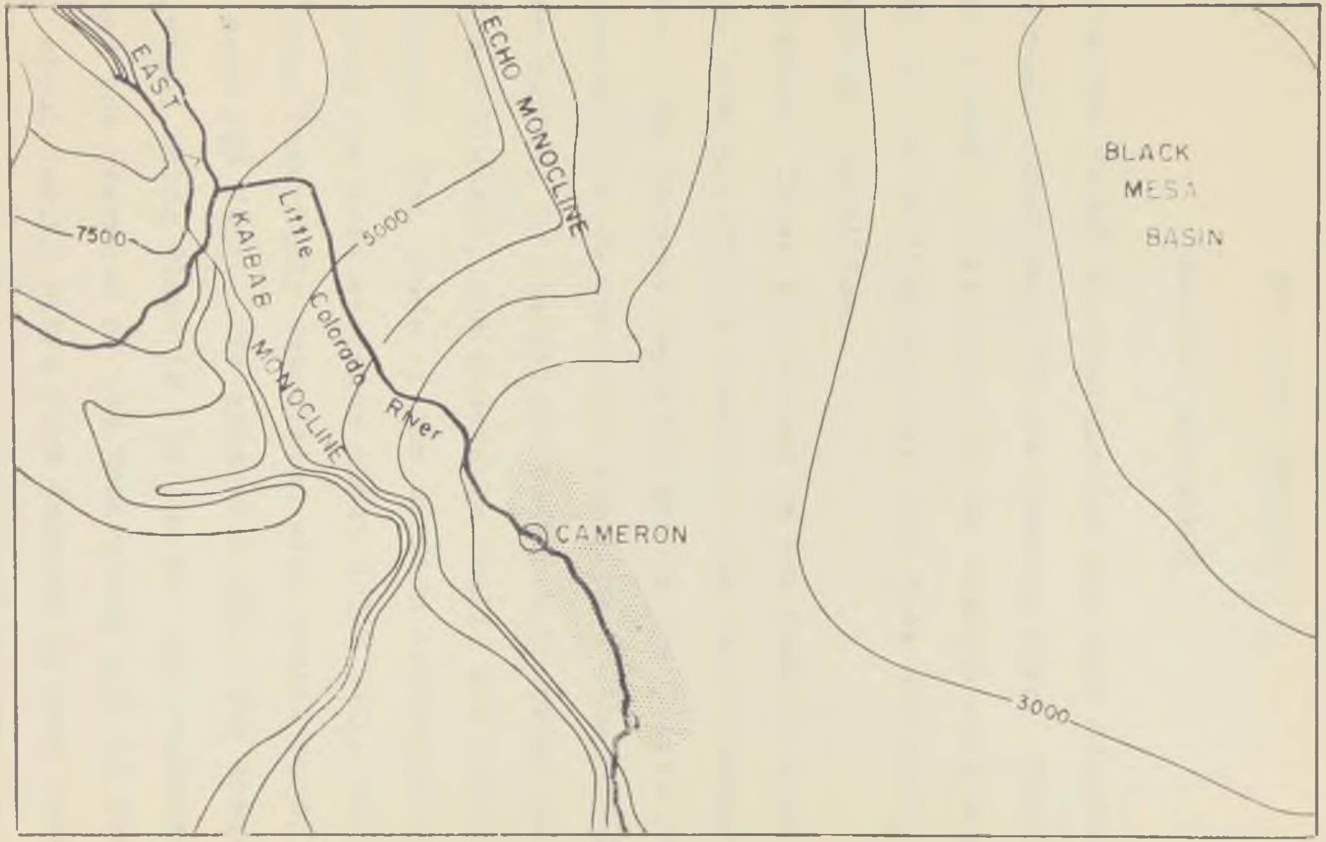
The Echo monocline flattens and its cliff diminishes in size southward to form Ward Terrace. Ward Terrace is an east-dipping cuesta which forms the east boundary of the report area, and part of the west flank of the Black Mesa Basin.

Black Mesa Basin The Black Mesa Basin is an elliptical structural depression located about fifty miles east of Cameron in northeastern Arizona. The Black Mesa Basin occupies an area of approximately 7,000 square miles and has a structural relief of about 800 feet. (Kelley, 1955). In topographic expression this structural basin appears as a mesa capped by Cretaceous sediments, and surrounded by older centrally dipping strata. (See Plate IV, page 25).

Faults

No major faults were observed in the Cameron area. Minor faults with displacement measured in inches were observed in the more competent sand lenses in the productive area, but they could not be traced into the surrounding clays. A more complete description of these faults is given in a following section.

PLATE IV



STRUCTURE CONTOUR MAP CAMERON & ADJACENT AREAS ARIZONA

Contours Drawn On Base of Kaibab limestone SCALE 0 — 20 miles

Contour Interval 500'

After Luedke & Shoemaker

ECONOMIC GEOLOGY

General statement

Uranium-vanadium minerals are the only minerals of known economic importance in the Cameron area. Vanadium occurs as a minor constituent in the uranium ores and is recovered in the milling process, but does not occur alone in commercial quantities.

Uranium, first discovered in the Cameron area in 1952, occurs in both the Chinle formation and the Shinarump conglomerate. The largest deposits are in the Chinle formation, and are restricted to the lower portions of the "C" division. These ore bodies, in comparison to those in other parts of the Colorado Plateau, are generally small, and somewhat discontinuous. The grade of the uranium ore which has been shipped from the area averages about 0.30% U_3O_8, but pockets of rich ore, invariably associated with fossil wood, have assayed over 10% U_3O_8. The ease with which the deposits can be developed, being close to the surface and enclosed by soft clays, and the nearness of the processing mill in Tuba, Arizona, about twenty miles from Cameron on good roads, account largely for the tonnage production from the area.

Commercial grade uranium ore has been produced from twenty deposits distributed throughout the Cameron area. Most of these deposits are small and it is estimated that only seven of them will exceed a maximum production of over 5,000 tons, and none is expected to exceed 30,000 tons. Several deposits have been exhausted after producing approximately fifty tons of ore.

Mineralization in small amounts is found throughout the upper parts of the Shinarump conglomerate. It is of small economic importance and is usually confined in the upper parts to a buff-colored, medium to fine grained, thinly bedded, cross laminated sandstone in association with carbonaceous material. No mineralization was found to be associated with the characteristic scours of the pre-Shinarump erosion surface, although such channels, of large proportions, are found in the area.

Uranium deposits in the Chinle formation of the Cameron area are of two types: (a) bedded or lens deposits, or (b) mineralized fossil trees. The two types are not commonly found in close association with each other.

Depositional environment of host rock

The environment under which the Chinle formation was deposited is described by McKee (1951) as follows:

> "Sediments of the Chinle illustrate a transition from dominently fluviatile conditions shown by cross-stratification, channeling and conglomerate lenses in the "D" member sandstones, to an environment of nearly continuous, quiet water deposition represented by the

muds and clays of the "C" member. Scattered lenticular beds of conglomerate and sandstone, similar to those found in the "D" member and the Shinarump, indicate intermittent fluviatile deposition."

Cross-bedding studies in these scattered lenticular sandstone beds in the "C" division, which are now uranium-bearing, indicate that the streams which formed them were flowing northward in this immediate area.

There is general agreement among students of the area concerning the nature of the surface of accumulation for the lower Chinle, but not as to the climate during the time of deposition. Many earlier writers considered the climate to have been arid to semi-arid. Dougherty (1941), on the other hand, envisions dense forests bordering permanent streams and swamp areas with more open forests in upland areas; a climate similar to that of the savannas in the tropics today.

The abundance of plant remains, and the preservation of the more delicate parts suggest little transportation of the material, followed by immediate burial.

Local tectonics

Several small east-trending flexures observed in the productive area north of Black Point and described in a previous section, were plotted on the area map. No obvious relationship between these structures and mineralized localities was observed, but due to the lack of accurate mapping of these structures exact relationships could not be established.

Many vertical fractures occurring as conjugate sets were observed in the more competent sandstones underlying the clays of the "C" division of the Chinle formation. The more prominent of these fractures appear on aerial photographs. After a stereoscopic study of the photos these fractures were marked thereon and then transferred to the base map. A prominent set of these fractures strikes northeast and a less prominent set strikes northwest. A contour diagram was constructed from 364 of these fractures plotted on an equal-area net, and appears on Plate V, page 38. The pattern and concentration of these fractures, masked by soft clays in the vicinity of the mines, did not appear to have any significant relationship to the location of mineralized areas.

Numerous fractures and small faults were observed within the sandy ore-producing lenses. These small-scale features were mapped in detail in the Huskin Number 1 mine, and are discussed in a following section.

Regional folding and faulting appear to have exercised no direct control on the trend or position of individual ore bodies in the Cameron area. Although this appears to be a general observation in the Colorado Plateau, Kelley (1955) states:

> ". . .it is shown that indirectly the tectonic events of the past, probably as far back as Permian time, have had a most important bearing upon the distribution through other geologic factors that may have contributed directly to the origin and distribution of ore. These

factors are (1) provinces and environments, (2) paleo-hydrology (3) igneous activity and (4) erosional history or geomorphology."

As a possible influence on the occurrence of uranium in the Cameron area, the following is worthy of note. McKee (1951) states:

"The first extensive uplift in Arizona after the Pre-Cambrian probably came during the Upper Triassic Epoch. At that time the region south of the Colorado Plateau apparently was uplifted for the Shinarump conglomerate of Late Triassic age, deposited as a broad sheet of gravel over much of northeastern Arizona and adjoining areas, testifies to vigorous erosion with long transportation from an adjoining area. Among the gravels in this conglomerate are certain distinctive lithologic types and others contain diagnostic fossils which prove an origin to the south for much of the sediment."

During the deposition of the lower Chinle, the area north of Cameron near Cedar Ridge was a positive area whose terrain was above the general surface of accumulation as indicated by the absence of the Shinarump and a noticeable thinning of the Chinle. (McKee, personal communication, 1953). The drainage during Upper Triassic time, coming from the south and flowing generally northward toward the Cordilleran geo-syncline, appears to have been diverted to a more westerly course just north of the Cameron area.

Distribution of ore

Bedded or lens deposits Deposits of this type are similar in both stratigraphic position and lithology. Mineralization occurs within the lower sixty feet of the "C" division within elongate sandy lenses which possess certain distinct lithologic characteristics. The lenses represent scour-filling and are composed of muddy sandstone and sandy mudstone layers which contain varying amounts of carbon in the form of attritus with abundant fine particles and occasional logs. Mudstone flakes and flattened mudstone pellets of sand grain size often constitute the mudstone content of some of the sandy layers. Individual layers of sandy mudstones often attain a thickness of several feet and may be steeply cross-bedded, but usually cross-beds intersect at low angles. Sand grains within layers are subangular and are poorly sorted. Mudstones within ore-bearing lenses tested by X-ray spectroscopy contain the montomorillonite and kaolinite-types of clays, and sometimes small amounts of illite.

Colors within the lens range from black through brown and into tones of yellow. The darker colors usually reflect the amount of carbon present, but a dark manganiferous mineral called cobaltian wad (Austin, personal communication, 1956) is found as a coating on sand grains and also as discrete particles and accounts for some of the darker shades. (See Figure 8, page 53).

Sand lenses which occur in the lower parts of the "C" division generally posses a halo of altered claystone. This altered claystone is similar in texture and hardness to the surrounding rock, but is altered from the usual drab gray color to a light buff or yellowish-gray. This halo of alteration extends away from the lenses from a few inches to several feet.

Ore may occur anywhere within the lens, but it is found most abundantly in the lower parts, and favors the more sandy and carbonaceous layers. The continuity of many of these sandy lenses is difficult to determine from the surface because of erosion and alluvial cover, but future subsurface work may reveal fairly continuous networks of interconnected sandy lenses and stringers.

Mineralized fossil trees Distributed throughout the "C" division of the Chinle formation are innumerable fossil trees, occurring individually or in clusters, and in differing stages of petrification. Uranium minerals are found in and around an undetermined number of these fossil trees. Fossil trees appear to be more abundant in a zone about 120 feet above the base of the "C" division. Those which occur in the more sandy portions of the "C" division are more likely to be mineralized, but this observation is not definite.

This type of deposit usually consists of a carbonized or partly silicified uranium-bearing log, which often forms a protective capping to a mound or hummock of mudstone. (See Figures 3 and 4, page 34). The fossil tree usually has a halo of altered country rock, sometimes extending out several

FIGURE 3

View looking southwest from the east side of the Little Colorado River toward a silicified fossil tree capping a mound of clay developed in the "C" division, (Petrified Forest member) of the Chinle formation. The Black Point lava flow is seen on the horizon immediately over the fossil tree.

FIGURE 4

A close up view of a fragment of a uranium-bearing carbonized fossil tree from the "C" division (Petrified Forest member) of the Chinle formation. Shrinkage cracks filled with barite form the boxwork. The lighter colored crust is gypsiferous sand and clay.

Figure 3

Figure 4

feet from the tree. This halo usually contains jarosite, limonite and gypsum.

Detailed mapping

The lens deposit is typified by the Huskon number 1 mine. This deposit is approximately one mile east of Cameron, Arizona, on the north bank of the Little Colorado River, and occurs about sixty feet above the base of the "C" division of the Chinle formation. It is situated within several knolls and hummocks with the flanks of the lens well exposed. A large slice of rock had been removed from the center of the lens by mining operations which facilitated mapping. This ore-bearing lens is somewhat higher in the "C" division than other deposits, and is probably only slightly exceeded in stratigraphic elevation by the Huskon number 2 deposit. The strata dip one and one-half degrees to the northeast. The lithology of the surrounding material is typical of the lower "C" division in this area, predominantly mudstones of various colors composed mainly of montmorillonite clays. The ore occurs within an elongate lens of sandy material as has been described. (See Figure 5, page 41).

A topographic and geologic map depicting the extent of the lens material was constructed. (See Plate VII). This map indicates that the ore-bearing lens attains a thickness of about forty feet, and a width of about five hundred feet.

Because erosion has removed much of the surrounding material it is impossible to determine the exact length of the lens, but it probably was part of a channel several thousand feet in length. The long axis of the lens is oriented in a northeast direction.

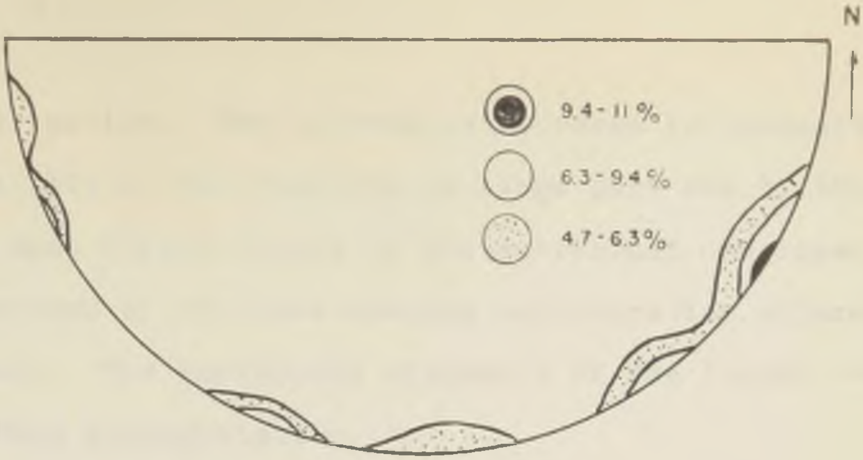
Fractures and small faults are numerous throughout the Huskon Number 1 deposit. Swift crumbling of freshly-exposed surface material limits the mapping of these features to areas of recent mining activity, and prevents tracing them into the surrounding area.

A prominent set of conjugate fractures trends northeast, parallel to the long axis of the lens, and dips at steep angles both southeast and northwest. A minor set trends southeast and dips to the southwest at steep angles. A contour diagram was prepared from 421 fractures which were mapped in this deposit and appears as Plate V, page 38. The attitude of many of the fractures, particularly those of the major set whose trend parallels the long axis of the lens, may be accounted for by differential compaction. Tension fractures would tend to form parallel to the long axis because of the greater compaction of the thicker clays along the flanks.

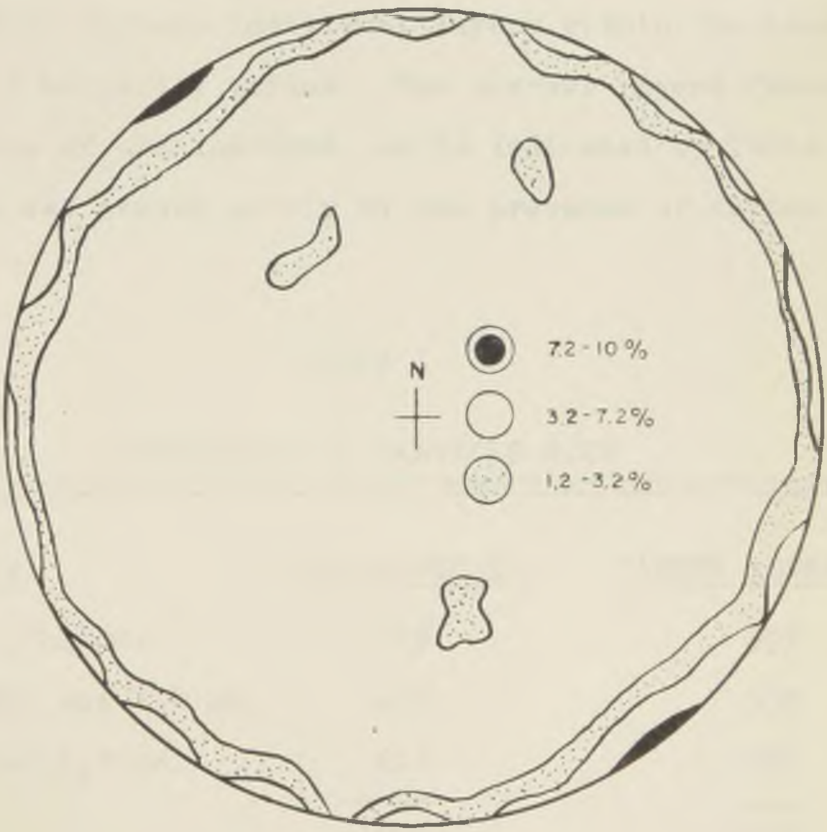
An overlay map showing the distribution of radioactivity was prepared for comparison with the fracture map. This overlay was constructed by recording the variations in radioactivity as indicated by a Detectron geiger counter as it was moved systematically over the surface of the mine. It was impossible to obtain direct radiation readings over an entire ore layer due to overburden. The total effect of the fractures within these more carbonaceous ore layers therefore could not be determined. It was observed, however, that individual fractures had no effect on radioactivity within or without the ore layers. As far as could be observed, a comparison of the fracture map with the radioactivity distribution overlay indicated that fracturing had no direct relationship to radioactivity.

Several faults of small displacement, both normal and reverse, were observed within the lens. These faults were of different ages, some displaced by others, and most were filled with gypsum. Figure 6, page 41, and Plate VI, page 42, illustrate a particularly interesting reverse fault which offsets a highly mineralized ore layer and an older fracture or fault. In places typical fissure filling appears to have taken place along this fault, as is illustrated by the photograph in Figure 7, page 43. Gypsum, barite and calcite occupy most of the fissure, but four stringers of a secondary uranium mineral (meta-autunite?) were observed with the aid of an ultra-violet light. Because of the close association of uranium and carbon, and the lateral extent of the mineralized horizon, it is believed the fault occurred after

PLATE V



364 FRACTURES
CAMERON AREA



421 FRACTURES HUSKON I MINE

CONTOUR DIAGRAMS

the mineralization. The noticeable increase in radioactivity in the vicinity of the fault is in large part due to the increased mass effect caused by the overthrust ore layer, and not because of increase uranium concentration adjacent to the fault. The horizontal alignment of the isorad contours supports this interpretation.

Grain size distribution A preferential distribution of sand grain sizes within the lens does not exist. However, sand grains within certain individual layers within the lens appeared to be partly sorted. The coarser layers favored the location of uranium ores, as is indicated by Table I. Coarseness was caused partly by the presence of carbon attritus.

TABLE I

COMPARISON OF PARTICLE SIZE

SIZE	ORE AGGREGATE	BARREN AGGREGATE
Less than .044 mm.	31%	59%
Between .044 and 1.0 mm.	48%	33%
Greater than 1.0 mm.	21%	08%
	100%	100%

FIGURE 5

View looking north at the right flank of the Huskon Number 1 ore-bearing lens, "C" division, Chinle formation.
Note the discordant bedding and the gravel capping.

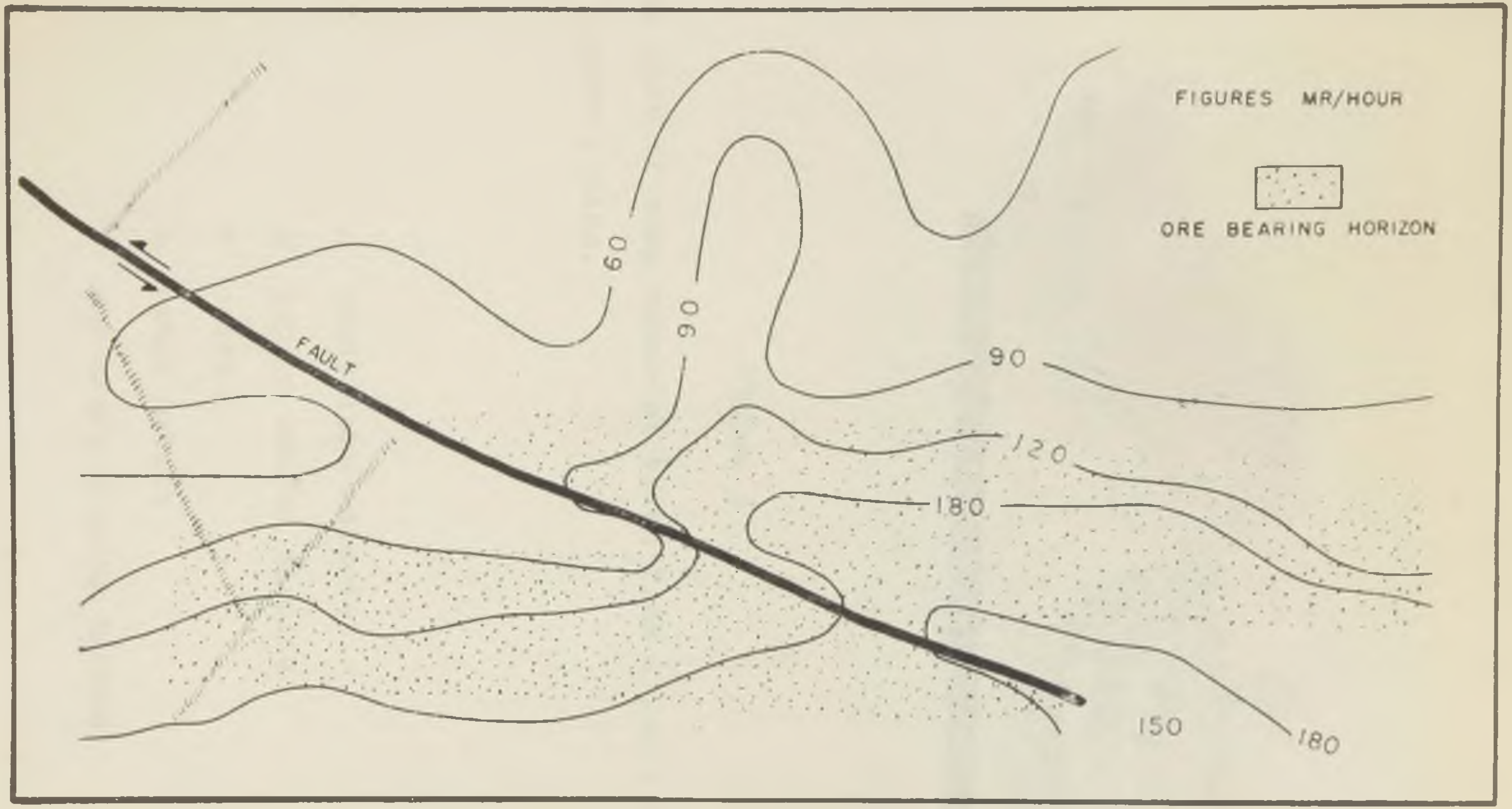
FIGURE 6

View of a reverse fault offsetting a mineralized layer and a gypsum filled fault of older age in the Huskon Number 1 mine. Red markers identify the offset ore layer.
See Plate VI for a radiation map of this ore face.

Figure 5

Figure 6

PLATE VI



ISORAD MAP, VERTICAL FACE

DEPICTING DISPLACEMENT OF MINERALIZED HORIZON

Figure 7

Close up view of some material taken from a fault in the Huskon Number 1 mine.

A sandy lens material

B gypsum and/or alunite

C calcite

D sandy matrix

U secondary uranium mineral

LABORATORY STUDIES

Exploration problem

In the Cameron area mineralization does not occur in all the sandy lenses which are situated within the favorable stratigraphic interval. There are numerous lenses within this interval which have essentially the same megascopic features as productive lenses, but contain no uranium minerals. The following methods were employed in an attempt to discover significant differences between mineralized and similar but barren lenses, which would be useful as guides in exploration.

Spectrographic analysis of selected samples

Samples were collected from two ore-bearing lenses and the surrounding country rock, and sent to R. A. Laverty, mineralogist, Atomic Energy Commission, Grand Junction Operations Office, who forwarded them to the Geochemistry and Petrology Branch of the Geological Survey, Denver, Colorado, for spectrographic analysis. These analyses were made to ascertain what elements were present and their relative abundances in the two environments. Table II indicates the elements tested by this method and a general concentration comparison between the lens material and the surrounding rock. A copy of the original data is included in Appendix I.

TABLE II

ELEMENTS TESTED BY SPECTROGRAPHIC METHODS

(Semi-quantitative)

More abundant in ore bearing lens	ELEMENTS TESTED	More abundant in surrounding rock
	Si	
	Al	- -
	Fe	
	Ti	-
- - - - - -	Mn	
	P	
- - - - - - - - - -	Ca	
	Sc	
	Sn	
	Sr	
	U	
	V	
- - -	Y	
- - -	Yb	
- -	Ge	
	La	
- - - - - -	Mo	
	Nb	
	Nd	
- -	Ni	
- - - - - - - - - - - -	Pb	
	Mg	-
	Na	
	K	
	Ag	
	As	
	Be	
- - - -	Cd	
- - -	Ce	
- - - - - - - - - - -	Co	
	Cr	
	Cu	
	Ga	

(- - - indicates increase)

Elements which occur in greater abundance outside the mineralized lens are aluminum, titanium and magnesium. Calcium along with manganese, molybdenum, lead, cobalt and several trace elements were more abundant within the lens. Cobalt was quite irregular in occurrence. The remaining elements showed insignificant or inconsistent variation.

Chemical analysis of selected samples

Financial restrictions limited the number of elements which could be analyzed by chemical methods. From the thirty-five elements spectrographically analyzed, molybdenum, manganese, lead, copper, cobalt and vanadium were selected as the most likely to have a spatial relationship to uranium, or to a favorable ore environment. They were selected on the basis of their geochemical habits and their abundance as indicated by the spectrographic analyses, and were analyzed by quantitative chemical methods.

Samples tested by chemical methods totaled twenty-six, and represented four general environments; a) the interior of a sandy lens, b) the halo of altered country rock around the lens, c)unaltered country rock adjacent to the halo, d) country rock not associated with alteration and sandy lens material. These samples were taken from both ore-producing lenses and lenses which were believed to be barren of ore. These analyses were made by H. E. Crowe, Geochemistry and Petrology

Branch, United States Geological Survey, and appear as Table V, Appendix I. It was observed from this work that the element molybdenum, was indicative of an environment favorable to the occurrence of uranium ores as is demonstrated by Table III.

TABLE III

AVERAGE MOLYBDENUM CONTENT

	PARTS PER MILLION
Productive lens material Ore Samples.	45.0
Productive lens material Non-ore Samples.	9.4
Barren lens material Non-ore Samples.	1.0

Although the spread is not great, the consistently low values from the non-productive lenses (mean deviation 0.09) indicate it is of value for geochemical prospecting and a guide in exploration.

The relationship between molybdenum and uranium possibly might result from a similar time of emplacement. The reducing conditions necessary to stabilize the uranium could precipitate the molybdenum as a sulfide, molybdenite. Hydrologic and oxidation conditions which were favorable for the preservation of one would also favor the preservation of the other. Problems which are connected with the genesis of the deposits are treated more fully in a following section.

The chemical analyses also indicated that the element cobalt, although quite erratic, would be of some value in differentiating between barren and mineralized lenses.

Field testing for Vanadium

In comparison with other uranium-producing localities on the Colorado Plateau, the Cameron area contains an abnormally small amount of vanadium or vanadium-bearing minerals. However, a study was undertaken to determine whether or not a significant distribution of vanadium existed in productive lenses and also to determine what differences existed between productive and non-productive lenses. The field testing techniques outlined by Ward and Marranzino (1953) were applied to 102 samples taken from barren and productive lenses representing four general environments as before described.

The vanadium testing procedure involved dissolving a finely-ground sample in hot sulfuric acid. Sodium citrate, versene solution, and stannus chloride were successively added to the solution and thoroughly mixed. When the solution was completely cooled, potassium thiocyanate was added, which under these conditions reacts with V^{+++} to produce a yellow complex ion or compound. Ethyl ether was then added to extract this complex ion. The yellow color of the complex ion dissolved in the ether was compared to standards to ascertain the vanadium content.

The results of this work formed a basis for the following three generalizations, besides substantiating the known fact that the area contained small amounts of vanadium.

1. 92% of the samples contained less than 0.03% vanadium.
2. The barren lenses contained progressively less vanadium outward from the center into the country rock than the corresponding part of a productive lens.
3. The difference noted above (2) is too small to be useful as a guide to uranium ore.

V_2O_5/U_3O_8 ratios

Vanadium-uranium ratios appear to have no systematic arrangement in the Cameron area. Ratios from producing mines varied by a factor of seven, from 0.09 to 0.63. This variation is abnormally high compared to the average occurrences on the Colorado Plateau. According to Riley and Shoemaker (1952) the "V_2O_5/U_3O_8 ratio within a small district generally varies by not more than a factor of three."

It was observed that considerable variation in vanadium-uranium ratios between non-ore samples taken from both productive and non-productive lenses was caused primarily by changes in the uranium content. The ratio for the non-productive lens was 11.8 and only 2.2 for the productive lens, but the average vanadium content varied only from 0.05% to 0.04% in these respective lenses.

Vanadium-uranium ratios appear to have no systematic arrangement within the Cameron area, but the location of the area relative to the Colorado Plateau appears to conform to the gross geographic V_2O_5/U_3O_8 pattern as described by Riley and Shoemaker by being ". . . . moderately low (less than 1) on the south and west sides" of the Colorado Plateau.

MINERALOGY

Known ore bodies in the Cameron area are near the surface and have become almost completely oxidized. Secondary uranium minerals, somewhat redistributed but generally associated with carbonaceous material, account for the bulk of the uranium. (See Figures 8 and 9, page 53). The richest ore is found in isolated fossil logs which are more deeply buried within productive lenses. The primary ore mineral, uraninite, is usually associated with pyrite, marcasite, galena and carbon. (See Figure 10, page 57). The cell structure of the wood is often preserved, and the cell centers are commonly filled by pyrite. (See Figure 11, page 57). Most specimens of primary ore show small fractures containing secondary uranium minerals and gypsum or barite. The presence of these secondary uranium minerals interferes with mass spectrographic age determination analysis, and for that reason this type of analysis was not undertaken.

The ore-bearing lenses are surrounded by a light brown to yellowish-brown alteration halo, as has been described, which contains a high content of jarosite and hydrous iron oxides.

The identification of the following minerals was primarily done in the Atomic Energy Commission mineralogy

FIGURE 8

Close up view of carbon attritus occurring in typical lens sediment.

FIGURE 9

Close up view of a fossil wood fragment that has been replaced by a secondary uranium mineral. (light color).

Figure 8

Figure 9

laboratory, Grand Junction Operations Office by R. A. Laverty, E. B. Gross and S. R. Austin from specimens collected by the writer. Within the ore-bearing lens the following gangue minerals have been identified: Quartz, muscovite, montmorillonite, kaolinite, illite, sericite, perthite, calcite, barite, smaltite, sphaerocobaltite, azurite, malachite, copiapite, halotrichite, beiberite, alunite, galena, greenockite, covelite, ilsemanite, pyrolusite and cobaltian wad (asbolan).

Principal ore minerals are torbernite, meta-torbernite, meta-autunite, schrockingerite, zippeite, uraninite, uranophane and beta-uranophane. Sabugalite and meta-zunerite have also been identified by Gruner (1954).

Paragenesis of an ore sample from the Huskin Number 2 mine is reported as follows: "There seems to be no overlap in the sequence of deposition." (Williams & Barrett, 1953).

1. Plant matter
2. Pyrite
3. Uraninite
4. Carbonate
5. Gypsum, barite, smaltite
6. Secondary uranium

More recent work by Austin (personal communication, 1956) however, indicates the paragenesis should include at least two stages of pyritization and introduction of marcasite.

Guides to ore occurrence

The following features are consistent in their association with uranium ore in the Chinle formation of the Cameron area, and are presented as useful criteria for exploration.

Stratigraphic position Most ore bodies of consequence have been found in the lower sixty feet of the "C" division of the Chinle formation, although mineralized trees may be found throughout this division.

Sandy lenses: Sandy lenses which occur within the lower sixty feet of the "C" division of the Chinle formation generally possess anomalous radio-activity.

Grain size: Within ore-producing lenses mineralization is more abundant in the medium to coarse-grained argillaceous sandstone layers than in the fine-grained argillaceous sandstone and mudstones.

Carbonaceous material: Carbonaceous material is favorable. Anomalous radioactivity is almost always found where carbonaceous debris is encountered.

Color: Light yellow, buff, and moderate rust color due to jarosite, limonite and other oxidation products are always associated with ore. These hues are particularly noticeable when viewed from the air and stand out in contrast to the surrounding grays.

Molybdenum: Molybdenum, present only in trace quantities, is more abundant in and around ore-bearing lenses than barren lenses.

FIGURE 10

Photomicrograph - of a polished section from a mineralized log sample from Ramco Number 17 Mine. Enlargement 120X

(a) galena

(b) greenockite

(c) pyrite

FIGURE 11

Photomicrograph - of the polished section described above

Enlargement 100X

(a) cell centers filled with pyrite

(b) uraninite

(c) carbon

(d) secondary uranium mineral

(e) gypsum

Figure 10

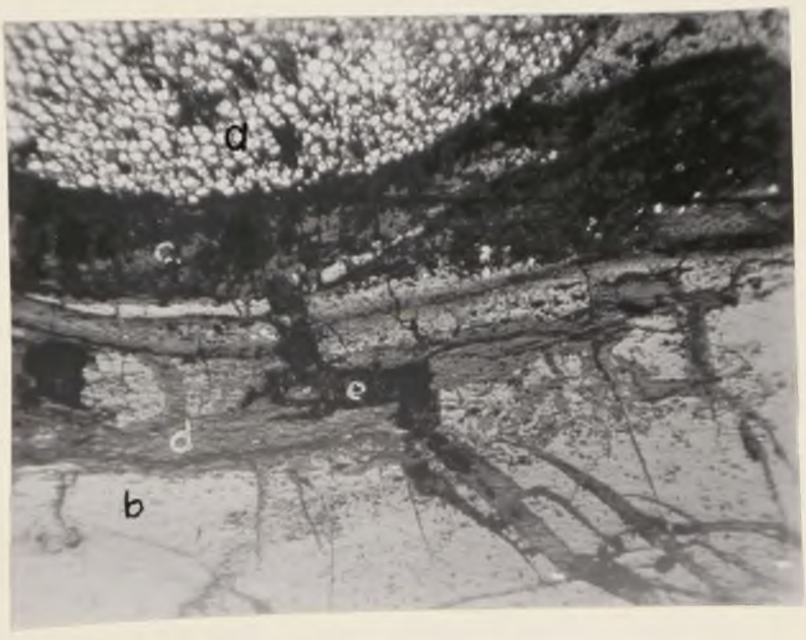


Figure 11

GENESIS OF THE ORE DEPOSITS

The origin of the uranium deposits of the Colorado Plateau is a subject of considerable controversy, and this investigation of the occurrence of uranium ores in the Cameron area, Arizona, has not resulted in its solution. However, there are several features associated with the Cameron ores which are worth emphasizing as they may have had a possible influence on its origin.

As background material the following brief outline is given of some of the current thoughts on the subject of the origin of uranium ores on the Colorado Plateau.

Syngenetic origin: Throughout the Colorado Plateau sedimentary features such as paleo-stream channels, carbonaceous debris and cross-bedding exhibit a marked control of ore bodies. Structural control is generally lacking and hydrothermal effects are not present or are not obvious. These conditions lead many observers to favor a syngenetic origin for the deposits. "The present position and form of the deposits would, according to this view, result from the combined effect of sedimentary deposition modified by diagenetic processes and later ground water action." (Wright, 1955).

Evidence on the relative age of the Plateau ores shows the mean age of many samples of ore is only 71 million years. (Stieff, Stern, Milkey, 1953). This corresponds to Laramide time however, and not Triassic or Jurassic as a syngenetic origin would require. Other factors not compatible with a syngenetic origin are: 1) the lack of appreciable quantities of heavy minerals within the deposits; 2) uranium is practically unknown as a placer mineral; 3) when concentrated by known sedimentary processes uranium is associated with fine-grained carbonaceous shale or phosphorite. (McKelvey, Everhart, Garrels, 1955).

Epigenetic origin: Suggested epigenetic sources of the Colorado Plateau uranium ores usually include the following two: 1) dispersed quantities in tuffs or ordinary rocks in the sedimentary column; 2) hydrothermal solutions.

The hypotheses that uranium and associated metals might have been derived from dispersed sources within the sedimentary column has been proposed by a number of geologists. In general it is believed that circulating waters collected the uranium and associated metals which were disseminated throughout the sedimentary rocks and released by the devitrification and weathering of volcanic ash. These metal-bearing waters, believed by many to have been of artesian character and controlled to a large extent by stratigraphic and structural features, deposited their load of dissolved ions upon contact with carbonaceous matter, earlier sulphides or other precipitating agents.

A hydrothermal source for the deposits is supported by the presence of pitchblende in several deposits, and by the occurrence of ore in numerous and widely separated stratigraphic horizons. The calculated Laramide age of the ore minerals does not necessarily support a hydrothermal origin and a hydrothermal source lacks the supporting evidence of conspicuous alteration.

Source of the Cameron ores

The occurrence of uranium in lens deposits in the Cameron area is similar in many respects to the Triassic deposits throughout the Colorado Plateau. The ore occurs in paleostream-channels in more permeable sands; it occurs most abundantly in the lower parts of the channels; and it is associated with carbonaceous material.

The most noticeable feature of the Cameron deposits in contrast to others on the Colorado Plateau is their occurrence within a thick clay section. Many of the deposits are apparently entirely enclosed by the clays, particularly in the case of isolated ore-bearing trees. However, it is possible that the lens deposits are part of an interconnected network of channels or sand stringers as has been mentioned.

The evidence against a hydrothermal solution as the source of the Cameron ores is the same as expressed for other localities. There is no conspicuous hydrothermal alteration. In addition to this there is the added difficulty of explaining the isolated ore-bearing trees and lenses. Fractures may have been the avenues by which mineralizing solutions gained access to otherwise inaccessible trees and lenses, but the effectiveness of fractures as passage ways in the clays of the Chinle formation is subject to question because of the tendency of soft sediments to seal openings.

The occurrence of the uranium deposits in the Cameron area is perhaps best explained as the result of uranium-bearing solutions, derived in part from: 1) the volcanic ash present in the Chinle sediments; 2) the parent volcanoes themselves; 3) a more deep-seated hydrothermal source whose location is unknown; or 4) a combination of several of these. These ore-bearing solutions probably flowed as surface or ground water during and shortly after the deposition of the lower Chinle sediments, saturating the entire region. The Cameron area possibly represents a somewhat restricted locality in which a propitious combination of sand lenses, carbonaceous material and paleohydrology favored the localization of the uranium ores.

GEOLOGIC HISTORY

The sediments of the Shinarump conglomerate and the sands of the "D" member of the Chinle formation were derived from high mountains, probably to the south of the Cameron area, and were deposited on a vast flood plain bordered by a seaway on the northwest.

Similarly during much of the remaining Upper Triassic time the vari-colored clays and muds of the "C" division of the Chinle formation were deposited on a low-lying flood plain traversed by sluggish streams, but occasionally inundated for short periods by the shallow waters of the seaway bordering on the northwest. The depositing streams generally flowed northward through tropical forests and swamps in the Cameron area, but were diverted to a more westerly course just north of the Cameron area because of the higher ground near the present site of Cedar Ridge, Arizona.

Volcanic material, largely tuff derived from volcanoes possibly located in eastcentral Arizona, was intermittently mixed with the products of erosion during the accumulation of the Chinle sediments.

Uranium bearing solutions, derived in part from the volcanic sediments, or the parent volcanoes, or from an undiscovered hydrothermal source, circulated in the surface drainage and in the subsurface aquifers. As deposition of the Chinle sediments continued, these migrating solutions and those solutions squeezed from the clays by compaction, were absorbed by the more permeable sandy lenses. These uranium-bearing solutions were either trapped in the sandy lenses with a subsequent, but not always co-extensive precipitation of uraninite and the sulfides of iron, lead and molybdenum, probably by the reducing action of organic substances, or migrated elsewhere via the more continuous sandy layers.

Successive sediments were deposited on the "C" division of the Chinle formation as shown in the stratigraphic column.

The crustal disturbance of the Laramide orogeny at the end of Cretaceous time formed the Kaibab and Echo monoclines, depressed the Black Mesa Basin, and raised the area to its present altitude. Erosion commencing during the Laramide uplift and interrupted sporadically since Quaternary time by volcanism which formed the San Francisco Mountains and adjacent lava flows, has continued until the present.

Erosion eventually progressed sufficiently to allow oxidizing conditions to reach the sandy lenses in the lower parts of the Chinle formation. The oxidation of the deposits caused a redistribution of much of the uranium as secondary minerals, and also instigated the bleaching of the lenses and surrounding clays by acids which were derived from oxidizing sulfides. In certain instances the uranium, and possibly molybdenum, was largely removed by leaching and ground water action. In other instances the uranium was preserved and now occurs within the sandy lenses and fossil trees of the lower Chinle.

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APPENDIX

TABLE IV

SPECTROGRAPHIC ANALYSIS DATA

Field No.	Si	Al	Fe	Ti	Mn	P	Ca
H#2-3A1	xx.	x.+	x.	.x-	.ox	0	x.
3A2	xx.	x.+	x.-	.x-	.ox+	0	x.-
3B1	xx.	xx.	x.-	.x	.ox	0	.x+
3B2	xx.	xx.	x.-	.x	.x-	0	x.-
3C1	xx.	xx.	x.	.x	.ox-	0	.x
3C2	xx.	xx.	x.-	.x	.ox-	0	.x+
H#3-3A1	xx.	xx.	x.-	.x-	.x	0	x.
3A2	xx.	x.+	x.	.x-	.ox	.x	x.
3A3	xx.	xx.	x.-	.x-	.ox-	0	.ox+
3C1	xx.	xx.	x.-	.x-	.ox	0	.x+
3C2	xx.	xx.	x.-	.x	.ox-	0	.x
3C3	xx.	x.+	x.-	.x-	.ox-	0	.x-

Field No.	Ce	La	Mo	Nb	Nd	Ni	Pb
H#2-3A1	.oox	.ox-	.ox+	Tr	.ox-	.ox+	.x
3A2	.oox-	.oox	.ox	Tr	0	.oox+	.ox-
3B1	Tr	.oox	.oox-	Tr	0	.oox	.oox
3B2	.oox-	.oox	.oox	Tr	0	.oox+	.ox-
3C1	.oox-	.oox	.ooox	Tr	0	.ooox+	.oox-
3C2	.oox-	.oox	0	Tr	0	.oox+	.oox-
H#3-3A1	Tr	.oox+	.oox-	Tr	0	.ox	.ox
3A2	.oox-	.oox+	.ox-	Tr	.ox-	.ox	.x-
3A3	0	.oox	.ox	Tr	0	.oox-	.oox+
3C1	0	.oox	.ooox	Tr	0	.oox-	.oox-
3C2	0	.oox	0	Tr	0	.ooox+	.oox
3C3	0	.oox	0	Tr	0	.ooox+	.oox-

NOTE: H#2 and H#3 refers to the Huskon number 2 and 3 mines. A refers to ore-grade lens samples. B refers to non-ore-grade lens samples. C refers to country rock samples.

TABLE IV (continued)

SPECTROGRAPHIC ANALYSIS DATA

Field No.	Mg	Na	K	Ag	As	B	Ba
H#2-3A1	.x	.x+	x.-	.ox-	0	Tr	.x-
3A2	.x	.x+	x.-	0	0	Tr	.ox
3B1	x.-	.x+	x.-	0	0	.oox-	.ox+
3B2	x.-	.x+	x.-	0	0	.oox-	.ox
3C1	x.-	.x+	x.-	0	0	.oox-	.oox+
3C2	.x+	.x	x.-	Tr	0	.oox-	.ox+
H#3-3A1	.x+	.x	x.-	0	0	Tr	.ox+
3A2	.x	.x	x.-	0	.x-	.oox-	.x
3A3	.x	.x+	x.-	0	0	.oox-	.ox
3C1	.x+	.x+	x.-	0	0	.oox-	.ox
3C2	.x+	.x	x.-	Tr	0	.oox-	.ox-
3C3	.x+	.x	.x+	Tr	0	.oox-	.ox

Field No.	Sc	Sn	Sr	U	V	Y	Yb
H#2-3A1	.ooox	0	.ox	.x	.x-	.ox	.oox-
3A2	.ooox	0	.ox-	.ox	.ox-	.oox	.ooox
3B1	.oox-	0	.ox-	0	.ox-	.oox-	.ooox-
3B2	.ooox+	0	.ox	.x-	.ox-	.oox	.ooox-
3C1	.oox-	0	.ox-	0	.oox+	.oox-	.ooox-
3C2	.oox-	0	.ox-	0	.ox-	.oox+	.ooox
H#3-3A1	.ooox	0	.ox	.x	.oox	.ox	.oox
3A2	.oox-	.ooox+	.ox+	.x+	.ox-	.ox	.oox
3A3	.ooox+	0	.ox	.x-	.oox	.oox	.ooox
3C1	.ooox+	0	.ox	0	.oox	.oox-	.ooox-
3C2	.oox-	0	.ox-	0	.oox	.oox	.ooox
3C3	.ooox+	0	.ox-	0	.oox	.oox	.ooox

Field No.	Be	Cd	Ce	Co	Cr	Cu	Ga
H#2-3A1	.ooox	.ox-	.ox	.x-	.oox-	.x-	.ooox
3A2	.ooox-	0	.oox+	.ox	.ooox	.oox	.ooox
3B1	.ooox	0	.oox+	.oox+	.oox-	.oox	.ooox+
3B2	.ooox-	.ox-	.oox+	.ox	.oox	.oox+	.ooox+
3C1	.ooox	0	.oox+	.ooox+	.oox-	.oox+	.ooox+
3C2	.ooox-	0	.oox+	.ox	.oox-	.ox+	.ooox
H#3-3A1	.ooox	.ox-	.ox-	.x-	.oox-	.oox	.ooox
3A2	.ooox	.oox+	.ox-	.ox	.oox-	.ox-	.ooox
3A3	.ooox	0	.oox+	.oox	.oox-	.oox	.ooox
3C1	0	0	.oox+	.oox	.oox-	.oox	.ooox
3C2	.ooox-	0	.oox+	.oox-	.oox-	.oox	.ooox
3C3	.ooox-	0	.oox+	.oox-	.oox-	.oox	.ooox

NOTE: H#2 and H#3 refers to the Huskon number 2 and 3 mines. A refers to ore-grade lens samples. B refers to non-ore-grade lens samples. C refers to country rock samples.

TABLE V

CHEMICAL ANALYSIS DATA

	PERCENT				PPM			
Field No.	U_3O_8	V_2O_5	$CaCO_3$	Cu	Pb	Co	Mn	Mo
XR-1	0.0010	0.014	1.207	0.003	50	<10	50	<1
2	0.0004	0.015	2.725	0.051	20	10	250	<1
3	0.0023	0.020	1.572	0.011	50	<10	20	1
4	0.0028	0.017	1.394	0.016	20	10	100	<1
5	0.0021	0.016	14.471	0.260	20	50	500	<1
6	0.0048	0.030	1.909	0.003	<20	10	50	<1
7	0.0033	0.017	3.988	0.264	20	20	500	<1
8	0.0006	0.012	9.765	0.012	50	<10	70	<1
9	0.0017	0.019	4.172	0.006	100	<10	20	<1
10	0.0107	0.020	4.400	0.000	130	<10	<10	2
H#1-BN	0.0122	0.016	2.996	0.001	20	<10	20	6
1-BS	0.0050	0.013	1.770	0.006	100	<10	100	2
2-BT	0.0151	0.017	0.251	0.000	70	<10	20	60
3-B	0.0010	0.017	1.877	0.011	70	<10	<10	25
3-BS	0.0172	0.010	0.982	0.048	20	500	150	1
7-B	0.0376	0.016	1.529	0.004	50	100	50	<1
8-BN	0.0134	0.054	1.066	0.017	20	20	100	<1
8-BS	0.0142	0.016	1.002	0.001	<20	20	50	<1
10-BE	0.0052	0.045	3.126	0.043	<20	10	100	<1
10-BW	0.0071	0.110	2.073	0.051	<20	100	100	<1
2-A1	0.638	0.259	4.651	0.050	4500	2000	100	100
2-A2	0.092	0.048	3.630	0.001	200	500	200	30
2-A3	0.212	0.031	2.949	0.001	70	500	300	5
2-B1	0.019	0.026	1.900	0.001	150	70	100	5
2-C1	0.005	0.020	0.652	nil	50	<10	<10	2
2-C2	0.032	0.028	1.673	0.071	50	300	10	<1

NOTE: H#1 and etc. refers to the number of the Huskon mine. XR refers to barren lenses. A refers to ore-grade lens samples. B refers to non-ore-grade samples from productive lenses. C refers to country rock samples.

For 2 Maps see Map Case under call number